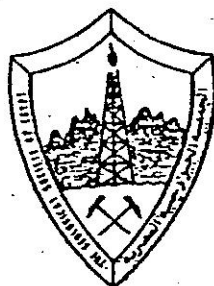


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**PEDOGENESIS AND RELATED GIBBSITE AND
NATROALUNITE FORMATION IN UM GEREIFAT
AREA, RED SEA COASTAL ZONE, EGYPT.**

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lateritization, bauxitization, gibbsite, natro-
alunite, calcimorphic paleosol

Two well preserved types of paleosol of different stratigraphic settings and modes of formation are detected and studied in Um Gereifat area, Red Sea, Egypt. These are:

- 1. Pre-rift acid alumino-ferruginous latosol, and*
- 2. Syn-rift alkaline calcimorphic paleosol.*

The mineralogical composition, textural characteristics and pedogenesis of these paleosol types are analysed and discussed. Their paleotopographic and stratigraphic significance are deduced.

The first paleosol type represents remnants of pre-rift paleoerosion surface and resulted during a prolonged period of soilification of Precambrian granite under intensive leaching conditions of tropical to subtropical paleoclimate. It is concluded that this paleosol type was generated through three stages induced lateritization and secondary bauxitization with gibbsite formation during periods of active weathering followed by a fourth stage of natroalunitization during the general desiccation of the produced laterites.

The second paleosol type is genetically related to a syn-rift paleokarst event during a time of uplift and sea-level fall and under semiarid paleoclimate and vegetation cover.

The paleoerosion surfaces and related paleosols or duricrusts of Um Gereifat rift sector are used for recognizing the paleotopographic evolution of this sector.

INTRODUCTION

Some attempts have been made to elucidate the importance of the paleoerosion surfaces of the Egyptian Neogene succession of the Red Sea coastal zone in the formation of a characteristic surficial rock associations,

duricrusts and economic mineral deposits (El Aref and Amstutz, 1983; El Aref and Ahmed, 1986; El Aref et al., 1985, 1986; El Aref, 1984, 1993). Among these attempts, El Aref (1993) has identified three main syn-rift events of emergence and paleokarstification, with or without mineralization. These are: a) intra-Um Mahara paleokarst (K_1); b) post-Um Mahara- pre Abu Dabbab paleokarst (K_2) hosting celestite and, c) post-Um Gheig paleokarst (K_3) hosting Pb, Zn, Fe sulphides and barite. The K_3 paleokarst event was responsible for the configuration of the present day karst landforms of the Red Sea coastal zone and is genetically related to the Plio-Pleistocene pluvial periods and the Quaternary runoff regimes.

Further study and field investigations in the Um Gereifat mine and the surrounding areas (Fig. 1) led to the recognition of two contrasting types of paleosols of different stratigraphic setting and modes of formation: a pre-rift acid latosol and a syn-rift alkaline calcimorphic paleosol. This work aims at explaining the stratigraphic and paleotopographic significance of these paleosols and the pedogenetic processes and paleoclimatic conditions that prevailed during their formation. The observed paleosol profiles were measured and divided into characteristic horizons on the basis of the degree of weathering of the parent rocks and on the composition, textures and stratigraphic sequence of the weathering products. The two paleosol profiles were sampled and a large number of representative thin and polished sections were examined microscopically. The mineral identifications were confirmed by X-ray diffraction analysis. Some representative samples from the pre-rift latosol profile have been analysed by XRF to highlight the general variation trends of the major oxides during the pedogenesis.

Um Gereifat mine was an ancient site for red ochres. Moharam (1959) related these ochreous deposits to hydrothermal quartz veins cutting Precambrian diorite and granite. However, in the current literature, these deposits were treated and described as an oxidized basal Middle Miocene horizon equivalent to that of the Pb, Zn and Fe sulphides of Um Gheig mine (El Shazly, 1957; Said, 1962) or as primary siderite replacement deposits (Kabesh et al., 1970). Tosson and Saad (1972) suggested shallow marine origin for these deposits. El Aref et al. (1986) described these deposits as product of Plio-Pleistocene paleokarstification. El Sharkawi (in Hussein and El Sharkawi, 1990) recorded the occurrence of alunite within the ochres and suggested that this alunite was formed during repeated weathering of green clay which also resulted in redeposition of ochres.

FIELD OBSERVATIONS

Figure 1 is a simplified geological map of the area surrounding Um Gereifat mine, showing the distribution of the Precambrian rocks towards the west and the eastward extension of the syn-rift sediments. The distribution, facies and thickness changes of the syn-rift stratigraphic units and included unconformities are clearly controlled by the rift dynamics (e.g. Montenat et al., 1986; Philobos et al., 1988; Purser et al., 1990; El Aref, 1993).

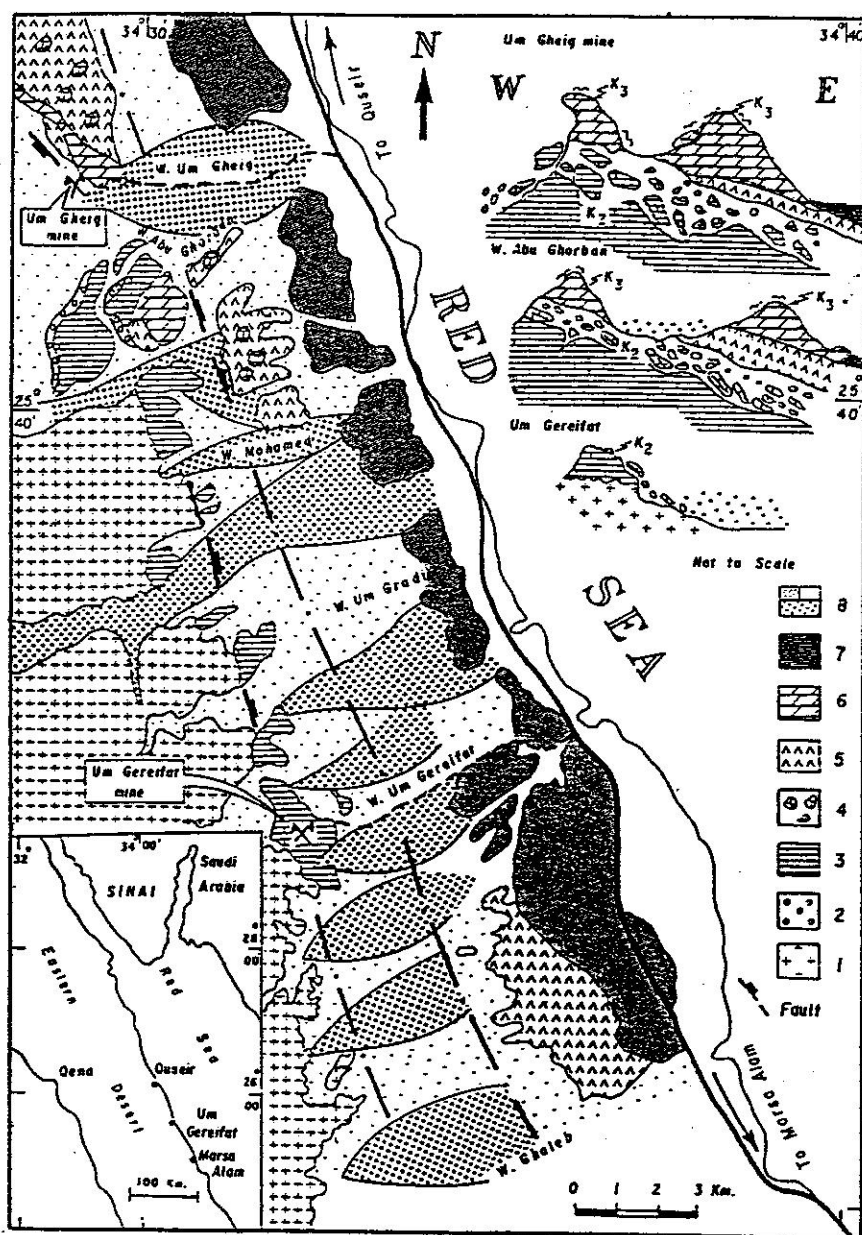


Fig. 1 Simplified geological map showing the location of Um Gereifat mine and the distribution of the different stratigraphic units. 1 = Precambrian rocks, 2 = Ranga Fm. (Late Oligocene-Early Miocene), fanglomerates; 3 = Um Mahara Fm. (Middle Miocene), mudstones and dolostones topped by paleokarst surface (K_2); 4 = rudrocks; 5 = Abu Dabbab Fm. (Middle Late Miocene), evaporites; 6 = Um Gheig Fm. (Late Miocene-Early Pliocene), dolostones; 7 = Undifferentiated Plio-Pleistocene marine and non-marine sediments; 8 = Holocene; SW-NE trending fanglomerates, wadi fills and beach sediments; K_2 = Post-Um Mahara - Pre Abu Dabbab paleokarst; K_3 = Post-Um Gheig (Plio-Pleistocene) paleokarst.

The proto-rift sediments are represented by the fanglomerates of the Ranga Formation which are unconformably overlain by the carbonates of the Um Mahara Formation. The two formations crop out along the western shoulder of the rift system, onlapping weathered Precambrian rocks and forming remnants of a dissected plateau. At Um Gereifat mine, the Ranga fanglomerates truncate laterite deposits which grade downward into weathered granites (Fig. 2). Northwards of Um Gereifat mine, the Ranga Formation and/or the Um Mahara Formation rest(s) directly above partially weathered basement rocks having no trace of laterite development. This can be attributed to the paleotopography of the Precambrian rocks and to the stripping of the top laterites before the deposition of the proto- or syn-rift sediments.

Intra-Um Mahara paleokarst surface, equivalent to K_1 surface of El Aref (1993) was previously observed by El Aref and Amstutz (1983) to the west of Wadi Abu Ghorban. On the other hand, the carbonates of the Um Mahara Formation are also terminated by a paleokarst surface corresponding to the K_2 paleokarst of El Aref (1993). The K_2 surface consists of a series of solution depressions and channels filled with collapse breccia and vadose cements (speleothems) and topped by a calcimorphic paleosol rich in rhizoliths and rhizocretions. The complete profile of this paleosol type is found in Um Gereifat mine area (Figs. 2 and 8). Along Wadi Um Gheig and Wadi Abu Ghorban, the K_2 surface slopes generally eastward and is covered by rudrocks, 4 to 10 m thick. The rudrocks are truncated by the Abu Dabbab Evaporite and/or the dolostones of the Um Gheig Formation (sketch profiles, Fig. 1). They consist mostly of matrix-supported, angular to subangular, block to sand size carbonate fragments; while igneous and metamorphic boulders and pebbles are less abundant. The carbonate fragments were clearly derived from nearby or underlying karstified and pedogenetically modified rocks of the Um Mahara Formation as they comprise recrystallized mudstones, calcified dolostones, crustified calcite of speleothem type, calcified rhizoliths and rhizocretions as well as red-matrix breccia (rhizobreccia). The matrix between the carbonate fragments is formed mainly of sandy calcareous mud. Fragment/matrix ratio varies from one place to another. Lenticular bodies of sandstones and mudstones are also encountered within the rudrock succession. The rudrock components show signs of local gravitational slumping and short distance transportation and redistribution. They represent surface deposits accumulated within paleolows as a result of mass wasting assisted by running water and turbulent flow heavily loaded with coarse debris, most likely synchronous with or soon after the late stage of the K_2 karst event. Meanwhile, the karstified Um Mahara carbonate blocks to the west represents the paleohighs relative to the accumulating rudrocks in the paleolows to the east.

The exposed outcrops of the Abu Dabbab Evaporites and the dolostones of the Um Gheig formation form conspicuous cone karst and doline landforms (El Aref et al., 1986). The residual karst cone hills are often mantled by slope debris, talus and calcrete or gypcrete duricrusts. These

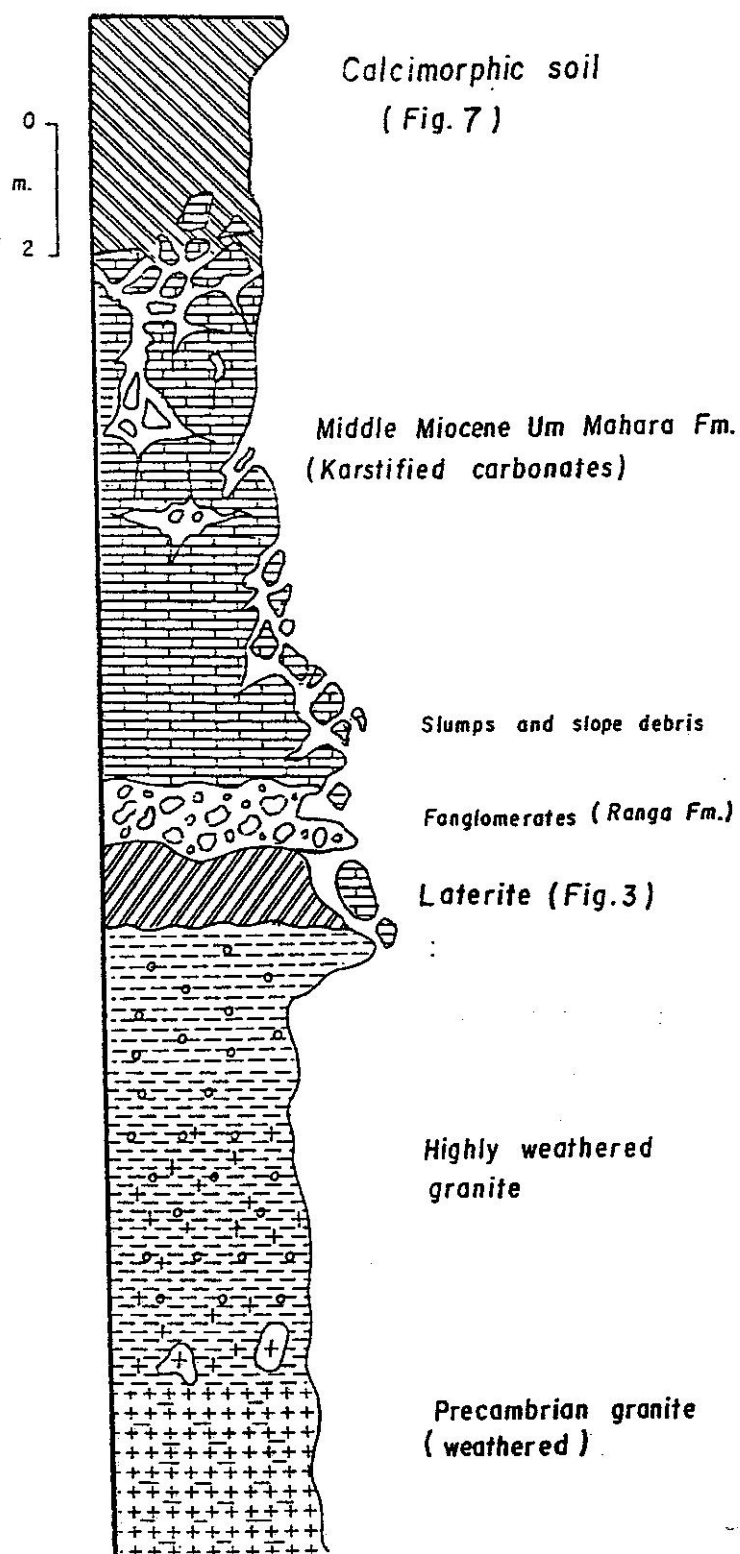


Fig. 2 Lithostratigraphic section showing the stratigraphic setting of the recognized paleosols.

landforms and the related surficial products and duricrusts belong to the post-Um Gheig K_3 paleokarst of El Aref (1993) which is related to the post-Um Gheig rift faulting accompanied by rising paleowater table and falling sea-level. Concomitant with the K_3 paleokarst event and the formation of the associated surficial products, Plio-Pleistocene marine and non-marine (pluvial) rock associations were deposited unconformably above seaward tilted blocks of the Abu Dabbab Evaporite; they form elongated masses of low relief close and parallel to the present day shoreline.

PRE-RIFT ALUMINO-FERRUGINOUS LATOSOL

The latosol profile comprises three main horizons, with gradual contacts, which reflect a series of weathering degrees ranging from slightly weathered granites to Al and Fe-rich laterites (Fig. 3). Each horizon has its own mineral associations and textural characteristics.

- Weathered granite (parent rock)

The exposed parent rock at the base is represented by slightly to moderately weathered granite, cropping out locally along the footslopes of the plateau remnants. The granite is generally massive, medium to coarse-grained and grey in colour; it is highly altered and mottled along joints and fractures. Towards the contact with the overlying saprolite horizon, the granite is progressively decomposed and succumbed into disaggregated mineral grains and rock fragments in a kaolinite-rich groundmass (Fig. 4a); the primary minerals are highly altered. Microscopically, the slightly weathered rocks are grey granite of granodiorite composition and well preserved hypidiomorphic texture (Fig. 4b). It consists of plagioclase, quartz, potash feldspar and biotite with less abundant hornblende. Zircon, apatite and magnetite are accessories. The feldspars are slightly to highly altered to fine-grained aggregates of sericite and kaolinite. Biotite is partially transformed into pale green mica (vermiculite), chlorite and deep yellow gel-like isotropic material, possibly "allophane"; iron hydroxide is often concentrated along cleavage planes. The hornblende crystals are completely altered to chlorite dissected by dense network of iron hydroxide veinlets (Fig. 4c). Sometimes, the main alteration products undergo partial to complete transformation into red stained kaolinite and iron hydroxide. The quartz crystals are commonly divided into smaller segments by kaolinite veinlets. The quartz segments are gradually separated from each other due to the expansion of the surrounding clayey matrix. The angular quartz fragments are highly corroded and display solution cavities suggesting silica dissolution.

- Saprolite horizon

This horizon is well exposed along the slopes of the plateau remnants. It attains up to 10 m thick and comprises thoroughly decomposed granitic minerals and rock fragments showing considerable enrichment in kaolinite and iron sesquioxides. The granitic rocks are friable, but they still retain their original texture in undisturbed sites. The feldspars, biotite, and hornblende are entirely transformed into kaolinite and goethite with or

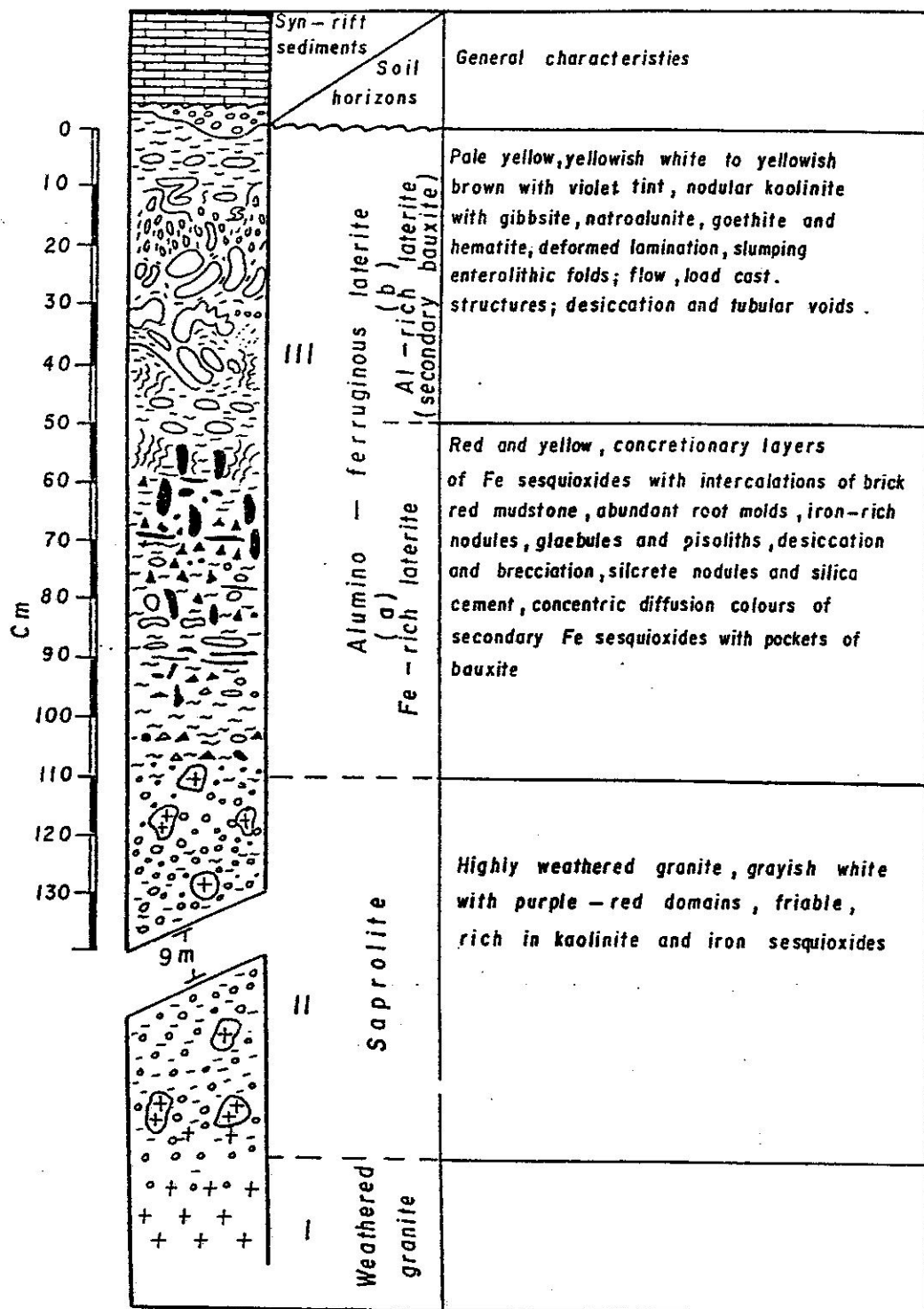


Fig. 3 Pre-rift latosol profile.

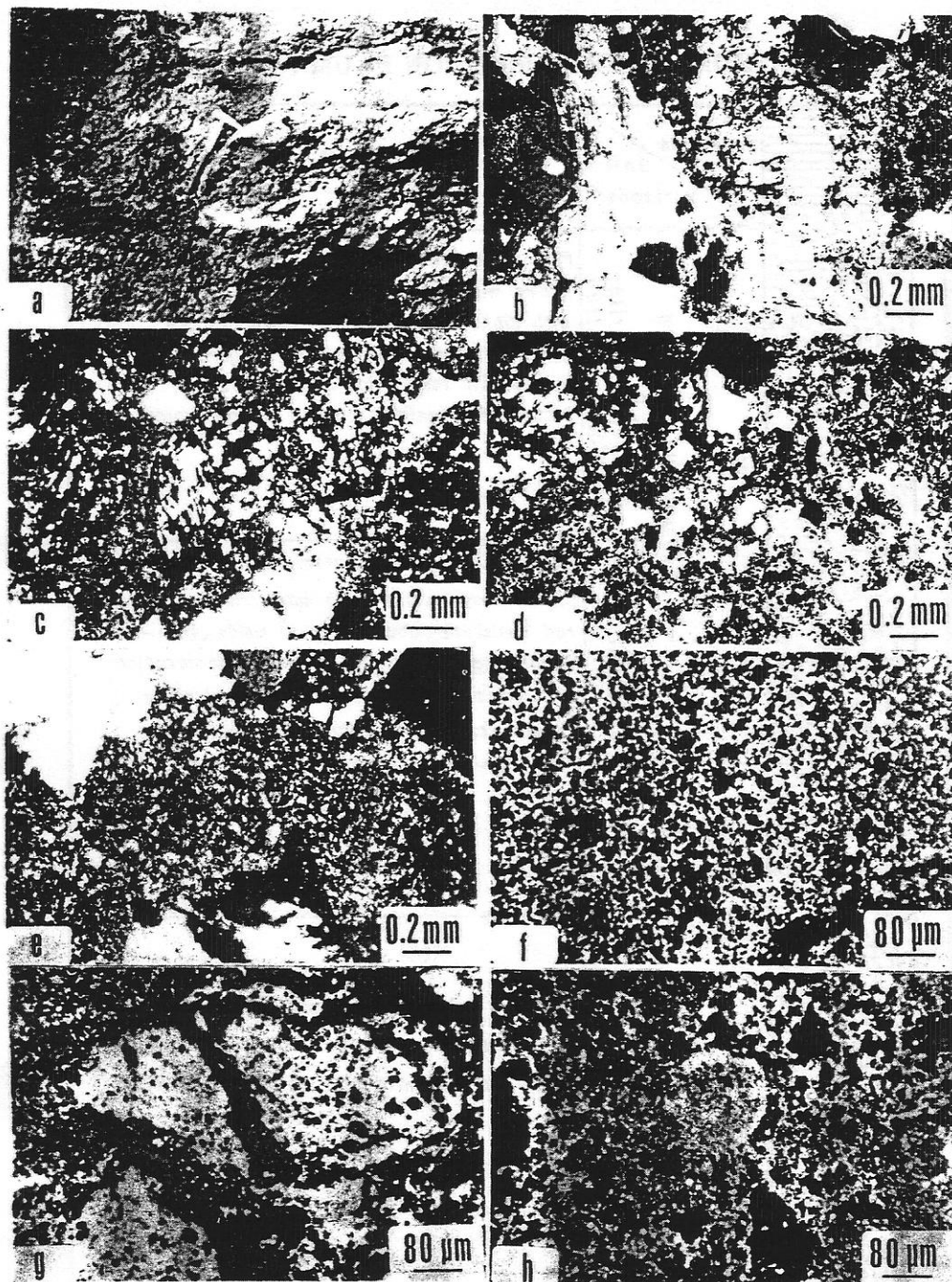


Fig. 4 a Highly decomposed and altered granite along the contact between the weathered parent rocks and the overlying saprolite horizon, latosol profile; b: Weathered granite with altered feldspars and biotite, C.P.; c: Pseudomorphs of hornblende dissected by dense network of iron hydroxide and surrounded by kaolinite-rich groundmass, P.P.L.; d: Quartz residuum floating in a kaolinite and iron sesquioxide-rich matrix, saprolite horizon, P.P.L.; e: Fine-grained and vermiform kaolinite within dislocated quartz fragments, P.P.L.; f: Pelitomorphic texture rich in clays and earthy goethite, Fe-rich zone, laterite horizon, R.L.; g: Lenticular masses of goethite in kaolinite-rich matrix, Fe-rich zone, laterite horizon, R.L.; h: A roundgrain (glaucofane) of earthy goethite coated by diffused clear goethite, Fe-rich zone, laterite horizon, R.L.

without amorphous "allophane" and micaceous minerals; chlorite is also decomposed into iron hydroxide. Original morphologic mineral features are sometimes preserved. Quartz and zircon are the most common resistant minerals. Quartz shows in situ fragmented and corroded grains floating in a groundmass of kaolinite and earthy goethite and hematite (Fig. 4d). The original granitic texture can be easily recognized in the lower part of this horizon, but it gradually disappears upwards, where kaolinite and earthy goethite and hematite dominate and the amount of quartz residuum and altered feldspars is considerably reduced. The upper part of this horizon is dominated by network of channels and tubular voids of variable diameters in which kaolinite and iron sesquioxides accumulated. Goethite generally remains associated with kaolinite, especially at places previously occupied by biotite, hornblende and chlorite. Isolated goethite glaeboles and pisolites are randomly scattered within the kaolinite-rich matrix. Kaolinite forms fine, weakly anisotropic aggregates often stained by iron; it occurs also as vermicular crystals forming granular aggregates or scattered at random within fine-grained kaolinite matrix. Vermicular growths are frequently observed in the interstitial matrix cementing dislocated quartz fragments (Fig. 4e). Kaolinitic clays show flow texture around individual quartz grains and altered feldspar crystals or fill microfractures and tubular voids.

- Laterite horizon

It attains up to 1.1 m in thickness and is divided into two zones: a lower Fe-rich (ochreous) zone and an upper Al-rich argillite (bauxitic) zone (Fig. 3). The boundary between these zones is manifested by the abundant distribution of stratiform nodules of kaolinite and gibbsite, either encrusted by diffused colloform goethite or embedded in ochreous matrix.

The lower zone, up to 60 cm thick, is recognized by its reddish colour. It is formed of alternating continuous and discontinuous layers and laminae of red to reddish yellow ochres and brick red mudstones, few millimetres to few centimetres thick. Silcrete nodules with quartz, dolomite and calcite cements form a characteristic hard interval within the middle part of this zone. The main megascopic and microscopic soil textures characterizing this zone can be genetically classified into the following types:

1. Textural types related to direct formation from fine-grained soil materials or soil colloids, with in situ segregation, rearrangement and adjustment of colloidal particles. They include: a) Pelitomorphic to microgranular textures, with 1-5 μm average particle size (Fig. 4f); b) Lenticular and patchy segregations of fine-grained kaolinite or earthy goethite and hematite in which silt-size quartz grains and vermiform kaolinite are scattered (Fig. 4g); they are of variable size and randomly oriented, but sometimes tend to be aligned parallel to the zone boundaries or around pores; c) Massive glaeboles and concentric pisolites of goethites with or without kaolinite and amorphous "allophane" (Figs. 4h, 5a); and d) Clay cutains developed along desiccation cracks and pore spaces.

2. Textural types produced by penecontemporaneous deformations as a result of hydration-dehydration, expansion-contraction and differential compaction. They include: a) Intraformational contortions and foldings (Fig. 5b), b) Desiccation structures grading from incomplete mud cracks to the formation of intraformational breccia (Fig. 5c), and c) Spastoids and circum granular cracks. The cements between the breccia fragments are chalcedony, microcrystalline quartz and idiomorphic quartz crystals showing coxcomb intergrowths and chevron texture; they are often followed by dolomite and blocky calcite.
3. Textural types indicating leaching, diffusion and redeposition of iron hydroxide. They include: a) Vertically arranged concretions of colloform goethite developed along fractures and desiccation cracks which become numerous in the upper part of this zone (Fig. 5d); b) Pore filling by massive goethite; c) Coatings of goethite around bleached clay-rich domains or glaebules (Fig. 4h, 5e); and d) Diffuse concentric layers of earthy goethite (liesegang rings) around cross cutting fractures.
4. Textural types of biogeneic origin, including tubules, root molds and root hairs as well as circular pores, microcellular and alveolar textures (Figs. 5a, f, g).

The uppermost Al-rich argillite zone (Fig. 3) is bauxitic in nature and is composed almost entirely of kaolinite and gibbsite with amorphous "allophane" and less abundant natroalunite, goethite and hematite. It is about 40 cm thick and consists of alternating white nodular layers and yellowish brown massive to slightly laminated layers. Worm burrows, tubular voids, shrinkage cracks and load casts are abundant in these layers.

The nodular layers pinch and swell or separate into horizontally arranged lenticular bodies. The enclosed nodules are spherical to oval in shape, 0.5-5 cm in diameter and of white, pale yellow and yellowish white colour (Fig. 5h). They are formed mainly of kaolinite, gibbsite and natroalunite. Such nodules are either randomly scattered within a kaolinite-rich matrix or closely packed and molded against each other with host kaolinite and iron sesquioxides restricted to thin intervening strings. The coalesced nodules are commonly irregularly crumpled, contorted and buckled giving rise to characteristic enterolithic and flowage textures (Fig. 5h). The stratiform arrangement of these nodules and their penecontemporaneous deformation features indicate formation from liquified soil products with interstratal supersaturated pore waters and suggest that the nodules were plastic at the time of their formation and deformations. Shrinkage of the nodules caused by dehydration resulted in the development of internal network cracks, in situ brecciation of the nodules and their ultimate separation into smaller angular to subangular pellet-like masses or intraclasts, either still partially connected or free floating in a matrix of kaolinite, gibbsite, natroalunite, hematite and goethite. Advanced intraformational reworkings during wet periods are evident by the local

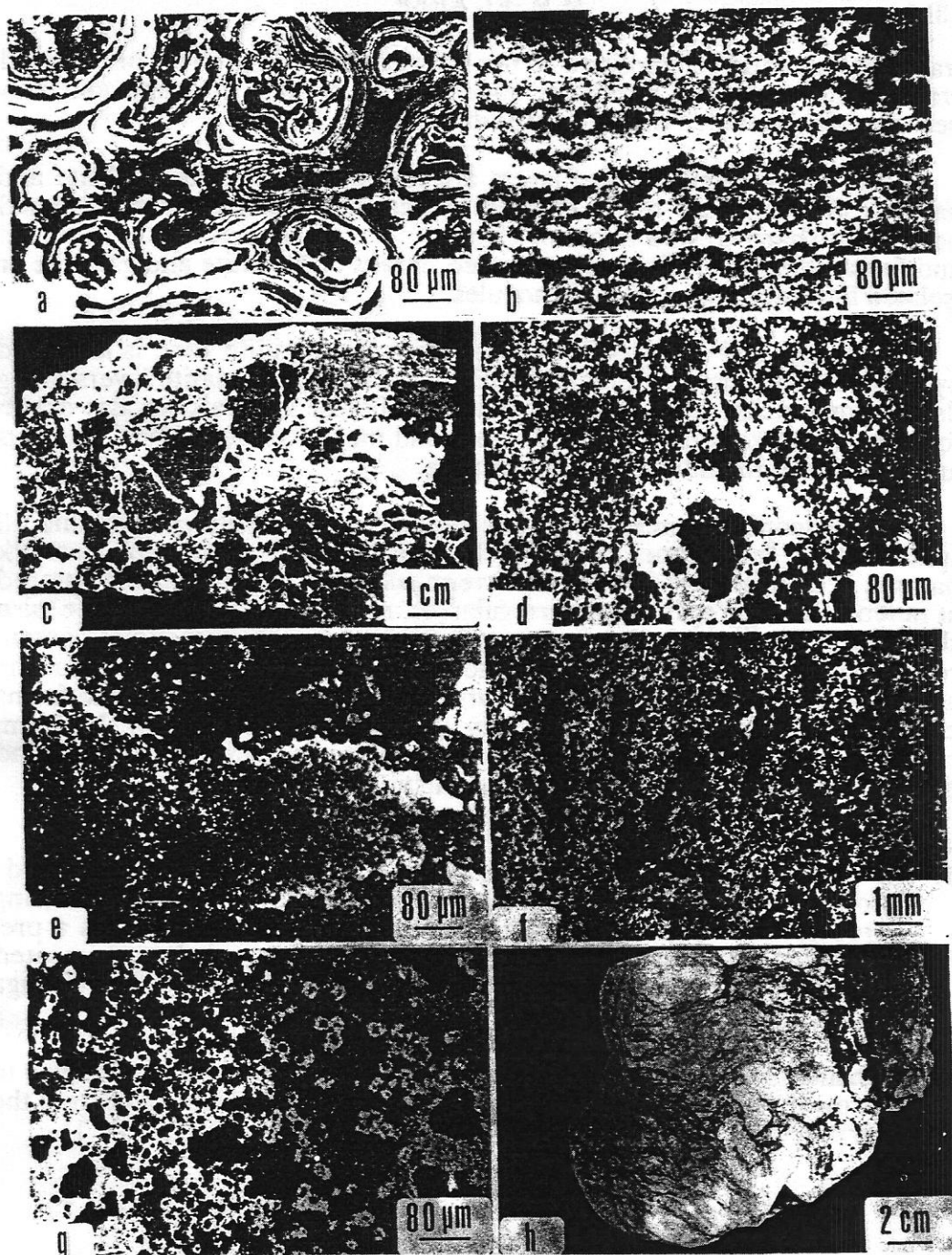


Fig. 5 a Concentric pisoliths of goethite and fine-grained kaolinite developed around areas of microcellular texture (arrows), R.L.; b: Intraformational corrugations in laminated earthy goethite and fine-grained kaolinite, R.L.; c: Laterite breccia with shrinkage cracks and cement of quartz, dolomite and calcite; d: Diffused colloform goethite developed along vertical fracture, R.L.; e: Coating of goethite around bleached clay-rich lenticular mass, R.L.; f: Root hairs infilled by clay within clay and earthy goethite-rich matrix, R.L.; g: Tubular voids and circular pores lined with goethite, R.L.; h: Closely packed and deformed bauxite nodules with host kaolinite and iron sesquioxides restricted to thin intervening strings, uppermost Al-rich zone, laterite horizon.

transportation and redeposition of the intraclasts within grooves or widened cracks. The reworked intraclasts appear more regular in shape and may become fairly rounded during transportation.

The intercalated massive layers are formed of kaolinite, gibbsite and natroalunite. They are highly cracked and crumbled and show a polygonal network of sharp-crested ridges or chips. Traces of lamination are observed and demarcated by horizontally arranged streaks of hematite and goethite or isolated flattened white, bauxitic nodules.

Leaching and redeposition of iron from this argillite zone is indicated by the abundant distribution of crustified goethite and hematite layers along desiccation cracks. Colloform encrustations of these minerals are also drawn together about centres of bleached clays and may filter down through joints and cracks into the underlying Fe-rich zone.

Microscopically, microcrystalline kaolinite and gibbsite corrode and fill spaces within "allophane" and may form subparallel streaks or network pattern. Kaolinite also forms twisted vermicular individuals, either scattered at random or aggregated into irregular or rounded knots. Gibbsite also shows delicately branched and contorted vermiforms that sometimes contain relics of kaolinite. Crystalline gibbsite also fills microscopic cracks cutting across kaolinite-rich nodules or the surrounding matrix. Natroalunite forms crypto- to microcrystalline aggregates or isolated crystals with 1-10 μm square cross sections, often concentrated around vermiform kaolinite and desiccation cracks or grow within fine-grained kaolinite and gibbsite.

- Pedogenesis and latosol formation

1. The development of the studied latosol profile indicates that the exposed Precambrian rocks were subjected to intensive deep weathering processes of tropical to subtropical paleoclimate. It demarcates a pre-rift paleoerosion surface (Early Oligocene ?) that was later truncated by the proto-rift Late Oligocene-Early Miocene fanglomerates (Ranga Formation).
2. Chemical analyses of the different units of this profile are employed to throw light on their general chemical characteristics and to portray the variation trends of the major oxides during lateritization (Table 1).

Table 1 Chemical composition of the different horizons and zones of the latosol profile.

Soil horizon	I	II	III IIIa	IIIb	aver.	
No.	1	2	3	4	5	6
SiO ₂	62.26	24.62	10.10	20.10	25.80	18.66
Al ₂ O ₃	13.98	28.50	23.60	30.01	42.70	32.10
TiO ₂	0.18	0.12	0.17	0.56	0.07	0.27
Fe ₂ O ₃	7.22	26.60	51.17	25.16	5.87	27.40
K ₂ O	1.92	0.28	0.01	1.06	1.75	0.94
Na ₂ O	2.39	0.08	0.01	2.01	2.16	1.39
CaO	1.42	0.10	2.50	0.07	0.94	1.17
MgO	0.34	0.30	1.16	0.09	0.06	0.44
P ₂ O ₅	0.06	0.43	0.28	0.07	0.10	0.15
MnO	-	0.10	0.28	-	0.09	0.12
L.O.I	7.02	18.92	9.16	19.16	17.29	15.20

L.O.I = Loss on ignition

I(1) = weathered granite, average of two analyses; II(2) = saprolite horizon, average of two analyses; IIIa(3) = Laterite horizon, Fe-rich zone, average of two analyses; IIIb(4) = laterite horizon, Al-rich zone, bauxitic matrix; IIIb(5) = laterite horizon, Al-rich zone, bauxitic nodule; III(6) = average composition of the laterite horizon.

3. Mineral and chemical composition of the investigated latosol profile can be compared with those of the acid alumino-ferruginous latosol of tropical to subtropical climate (Lelong et al., 1976).
4. The recognized horizons of the latosol profile suggest in situ soilification with continuous desilication and enrichment of Al and Fe. This is also supported by the considerable increase in Al₂O₃ and Fe₂O₃ and decrease in SiO₂ from the weathered parent rocks to the upper laterite horizon (Table 1).
5. The development of the different latosol horizons, their mineralogical and chemical compositions as well as the formation of gibbsite and natroalunite in the uppermost Al-rich laterite zone and the concentration of Fe₂O₃ in the Fe-rich laterite zone suggest three stages induced lateritization and secondary bauxitization during the periods of

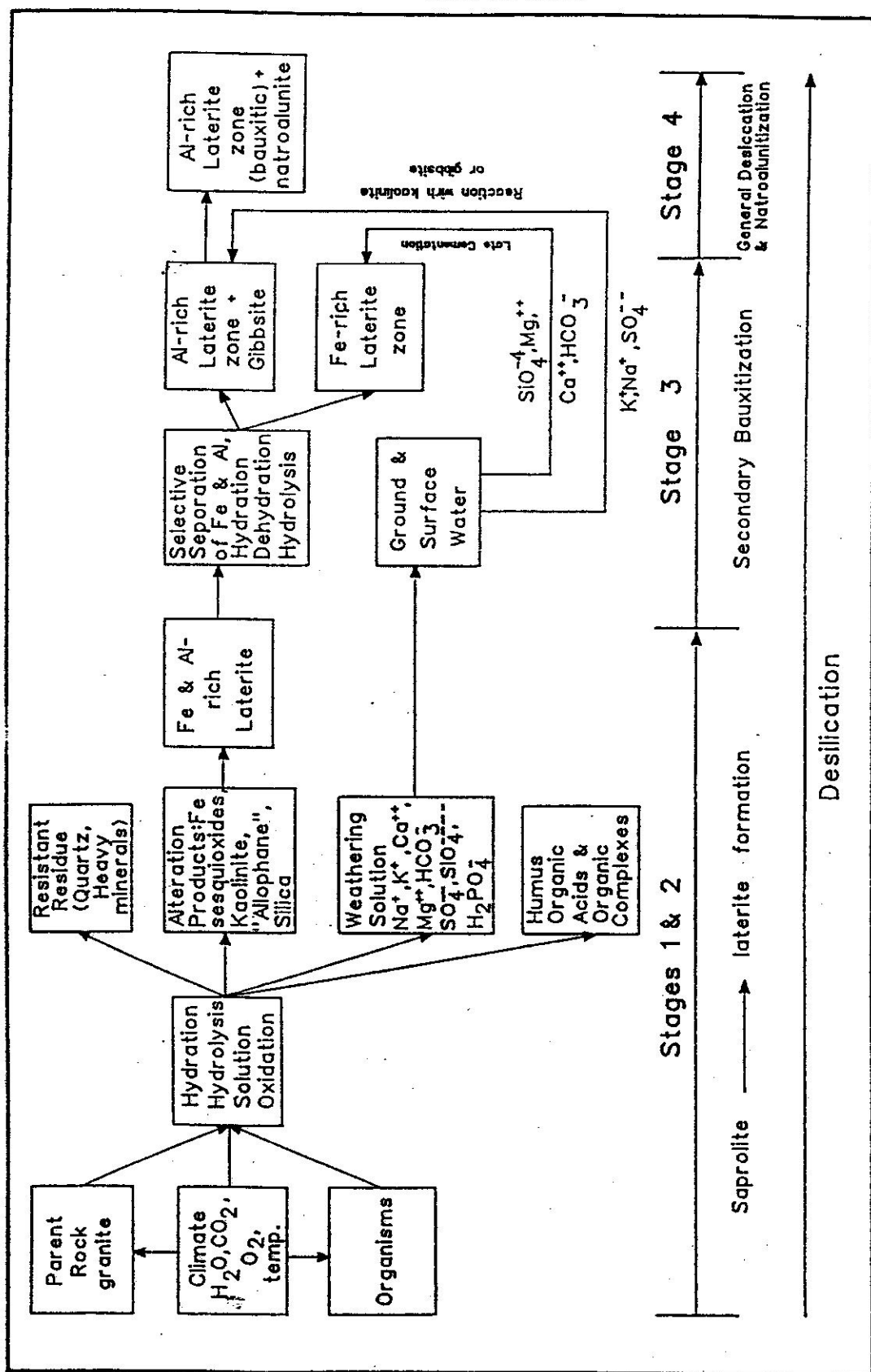


Fig. 6 The proposed stages of lateritization, secondary bauxitization and natroalunitization.

active weathering followed by a fourth stage (stage 4) of natroalunitization during the general drying-out of the laterites (Fig. 6).

Stage 1 displays the saprolite formation under fairly acidic environment and through which gradual desilication and hydrolysis of most Al-silicate and ferromagnesian minerals, leaching of the mobile components (e.g. Na^+ , K^+ , Ca^{++} , Mg^{++} , SO_4^{--} , H_2PO_4 , SiO_4^{-4} , HCO_3^-) and oxidation took place. The increased acidity of the soil system can be attributed to the production of organic acids during the breakdown of the organic matter and humus and concentration of CO_2 . During weathering, humus can react with iron and aluminum ions to form salt complexes which may subsequently undergo hydrolysis to yield hydrogen ions (Birkeland, 1984).

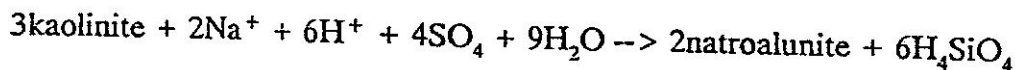
Stage 2 comprises continuous lateritization of the produced saprolite with complete mineral transformation, inducing continuous loss of silica and consequently the formation of an Fe- and Al-rich laterite horizon in the upper level of the profile.

Stage 3 is a bauxitization stage that appears to be responsible for the splitting of the laterite horizon (formed in stage 2) into (a) an uppermost Al-rich zone (known as secondary illuvial-eluvial bauxite, Lelong et al., 1976) and (b) a lower Fe-rich zone. This separation, which appears selective, is well known and is recorded in several worldwide laterite profiles. It is attributed to differential leaching and migration of Al, Fe and Si and formation of Al-hydroxide at shallow depths (aerated zone) which possess better permeability and groundwater circulation (Harden and Bateson, 1963; Lelong et al., 1976; Sastri and Sastry, 1982). The differential leaching of Al, Fe and Si depends on the prevailing Eh and pH soil conditions (Norton, 1973). In moderately acidic bicarbonic environment, Fe becomes relatively soluble and migrates downward, while Al remains immobile, and Si becomes increasingly soluble at higher pH (Norton, 1973). Downward migration and concentration of Fe in the studied profile is indicated by the secondary accumulation of goethite concretions and coatings and diffuse concentric layers along joints and cracks in the lower Fe-rich laterite zone; note the high Fe_2O_3 and low Al_2O_3 contents of this zone relative to the uppermost Al-rich laterite zone (Table 1). Other indications of such element differentiations are the high Al_2O_3 and SiO_2 and low Fe_2O_3 contents in the bauxitic nodules of the Al-rich zone relative to the surrounding matrix (Table 1). On the other hand, the development of gibbsite in the uppermost Al-rich zone indicates progressive hydrolysis of the formerly produced kaolinite in a slightly acidic soil environment with pH 4 to 7, where gibbsite is stable (Gardner, 1970). According to Lelong et al. (1976) the chemical reaction corresponding to this step is:



Stage 4 encompasses the formation of natroalunite in the uppermost Al-rich zone. Natroalunite is recorded only in this zone and is mostly

concentrated around vermiform kaolinite or grows within a kaolinite and gibbsite-rich matrix, suggesting formation at their expense. A noticeable decrease in K_2O and Na_2O is observed from the weathered parent rocks to the saprolite horizon and Fe-rich laterite zone, but they increase considerably again in the uppermost Al-rich zone (Table 1) which is compatible with the appearance of the natroalunite in this zone. Minerals of alunite group are recorded in different weathering products and laterite types (e.g. El Sharkawi and Khalil, 1977; El Sharkawi and Awadi, 1980; El Aref and Lotfy, 1989; El Sharkawi et al., 1990; Bird et al., 1989, 1990). As discussed by Bird et al. (1989, 1990), the alunite in regolith profiles are in equilibrium with evaporated meteoric waters which are quite different in isotopic characteristics to waters likely to be present in periods of weathering under humid conditions. The authors concluded that alunite formation may be completely unrelated to the periods of deep weathering and removal of soluble constituents and is related to the gradual desiccation of a regolith profile. Chitale and Guven (1987) related the formation of natroalunite in laterites to the reaction of acidic water charged with Na^+ with kaolinite as follows:



The upper limit of the natroalunite stability is $pH = 5.5$, above which gibbsite and kaolinite are more stable (Raymahashy, 1968). It seems then that the natroalunitization of the studied latosol profile can be attributed to the reaction of shallow evaporated groundwater charged with Na^+ with the kaolinite or gibbsite of the uppermost Al-rich zone, during the general drying-out of the laterites.

6. The quartz cement and silcrete nodules of the present laterites indicate redeposition of some of the free silica released through the weathering reactions of the foregoing stages and during the desiccation of the laterites under favourable low pH conditions. The subsequent late dolomite and calcite cementation indicates increasing pH values during the late phase of dewatering.

SYN-RIFT ALKALINE CALCIMORPHIC PALEOSOL

The complete profile of this soil type comprises four gradational horizons (Fig. 7) which elucidate the intimate relation between soilification and karstification of the host carbonate rocks. The biological constituents of this soil profile are highly calcified and ferruginated, thus forming a variety of organo-sedimentary textures which are virtually identical to those diagnostic of the pedogenetic calcrete or caliche described by many authors (e.g. Wright et al., 1988; Klappa, 1979, 1980; Arakel, 1982; Esteban and Klappa, 1983). Figure 7 shows the distribution of the main textures and features observed in the different horizons of this profile.

At Um Gereifat mine, the original marine rocks of the Um Mahara

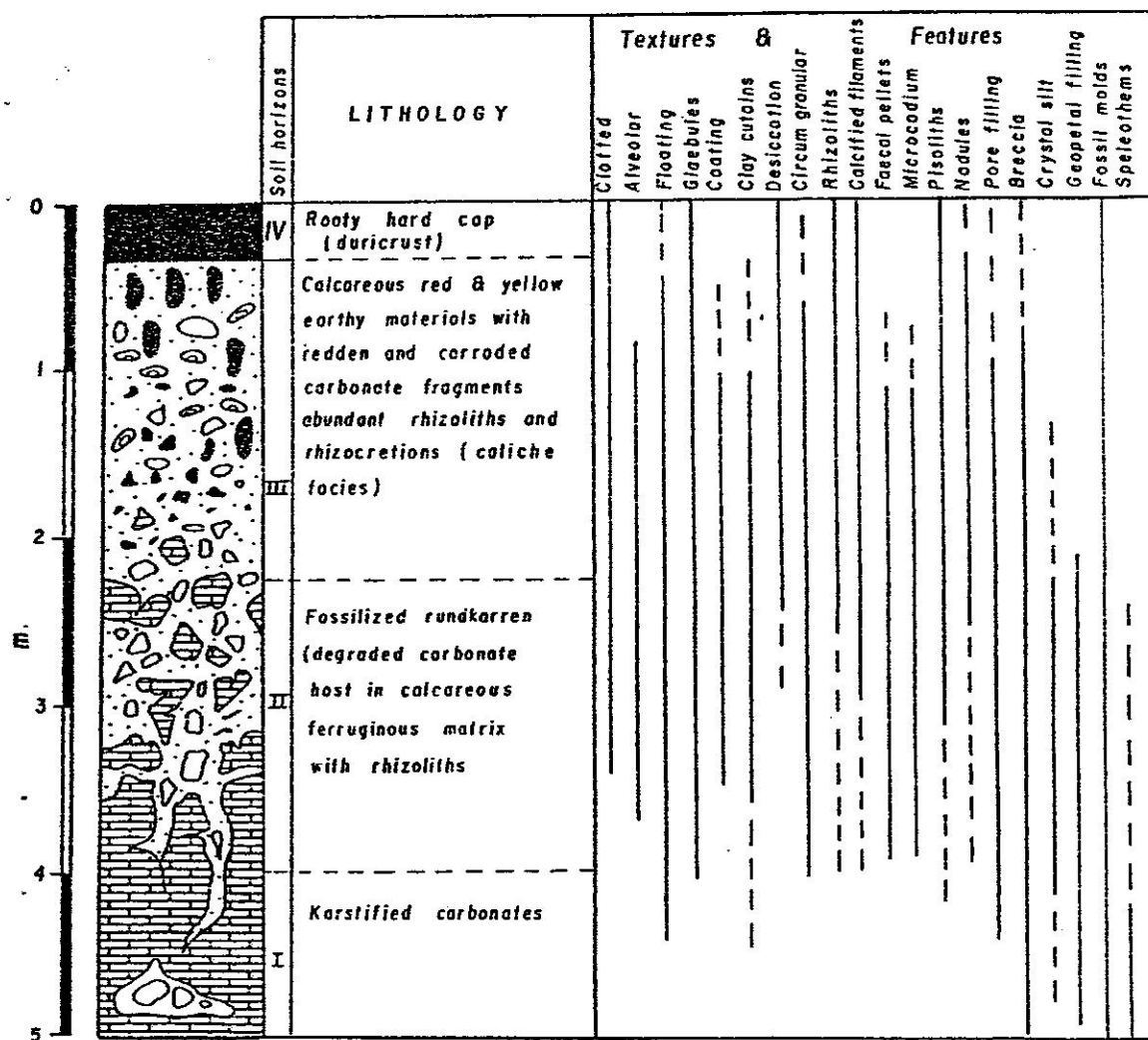


Fig. 7 Syn-rift calcimorphic paleosol profile.

Formation comprise repeated thin bands of algal mudstone, algal dolomitic mudstone and dolostone. Even and wavy laminations, laminoid fenestras, desiccation cracks and secondary displacive gypsum crystals and nodules are frequently observed within these lithofacies. Ghosts of bivalves and fossil molds are also encountered.

- Soil horizons

Horizon I of this soil type (Fig. 7) represents the karstified and pedogenetically modified country rocks which are dominated by solution cavities and passages, well developed along bedding planes and joints. Roof and wall collapse led to the enlargement and eventual destruction of the cavities and the production of rubble breccia. Small scale solution features are represented by nonselective void generation and continuous widening of the original fenestral cavities and desiccation cracks leading ultimately to the formation of network breccia. The original marine mud matrix is often recrystallized into microspar and the dolomite and gypsum crystals are replaced by mosaic calcite. The megascopic and microscopic solution openings are partially to completely filled with collapse breccia, gravitational vadose calcite cements (speleothems, Fig. 8a), residual iron sesquioxides, calcite crystal silt and calcareous mud. They often show geopetal internal fabrics. Laminar calcite fabric similar to the calcified root mats or algae described by Wright et al. (1988) and spherulites of siderite are also observed in some small scale solution features.

Horizon II, up to 1.65 m thick, represents a progressive stage of destruction of the country rocks as a consequence of dissolution and soil accumulation. It consists of degraded rundkarren showing transition from in situ crackle and network breccia into separated and randomly oriented fragments of variable sizes (Fig. 8b). Plant growths clearly assisted in the various stages of brecciation and concentration of residual iron sesquioxides. Branched plant roots are found within solution joints and between breccia fragments, forcing the rocks apart (Fig. 8c). Moreover, mottling of the fragmented rocks by Fe-rich reddish brown rhizcretions are common. Gradual upward solution rounding and size reduction of the carbonate fragments are characteristic. Red pigmentation of the carbonate fragments increases with decreasing particle size. The fragments are enveloped or infilled by particulate soily materials rich in iron sesquioxides, calcareous mud and fine angular debris. The soil matrix also includes abundant faecal pellets and rhizoliths of different forms, among which are concentrically coated spar-filled tubular voids, microcodium and calcified filaments as well as alveolar, crudely micro-laminar and cellular textures. Goethite- and micrite-rich glaebules and pisoliths with fine-scale anastomosing and circum granular spar-filled cracks are also present (Fig. 8d). The cements of these materials and fabrics are siderite, ankerite and blocky calcite.

Horizon III, up to 1.8 m thick, is essentially made up of isolated to packed calcified and ferruginated rhizoliths and rhizcretions in a partially consolidated reddish soil matrix. The rhizoliths may be so abundant to form continuous lenses, up to 30 cm long (Fig. 8e). They often contain or pass

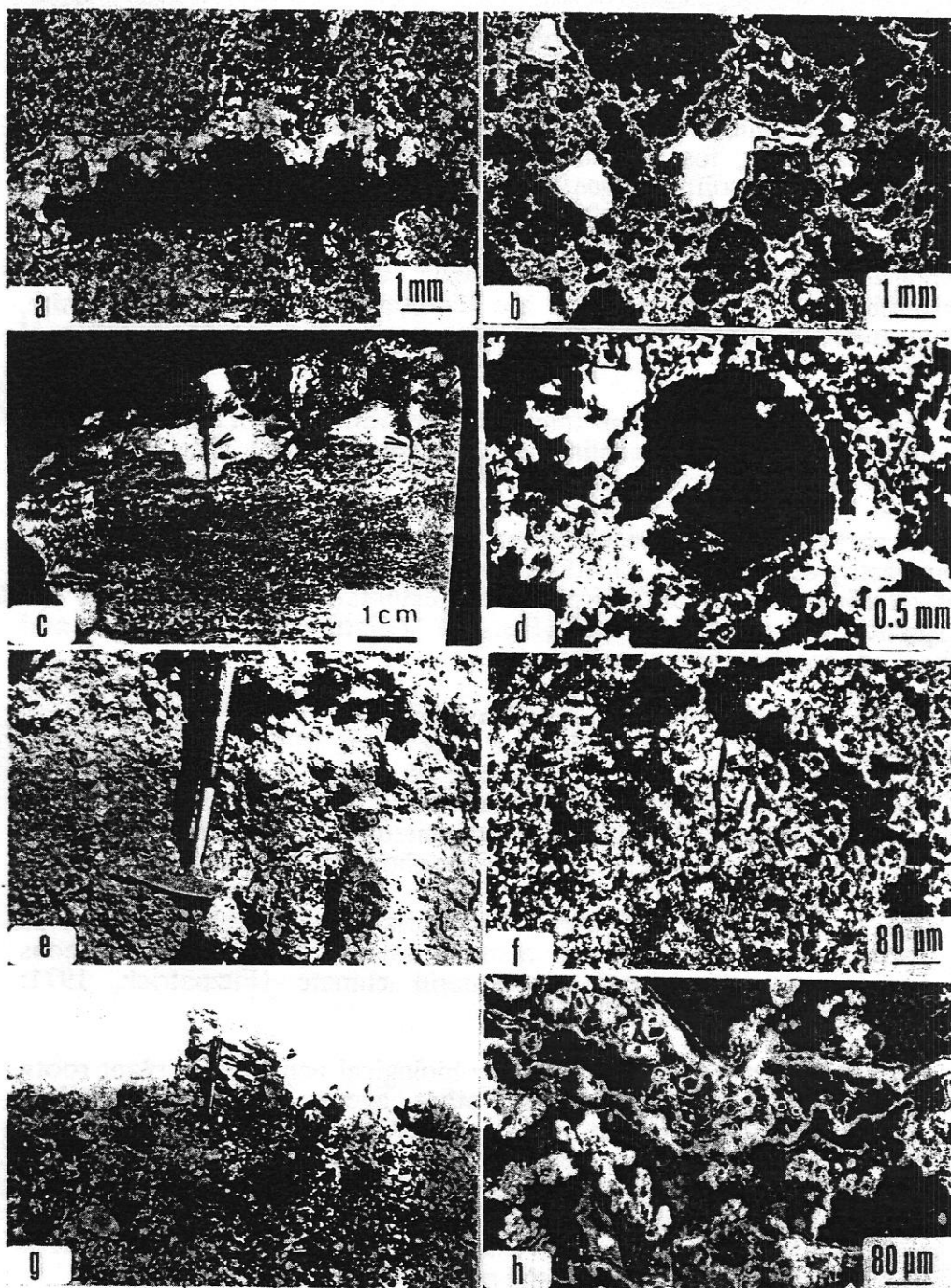


Fig. 8 a Microstalactites within solution cavity, calcimorphic paleosol, C.P.; b: Solution breccia fragments encrusted by calcite, C.P.; c: Root molds (arrows) within fractures. Notice, the mottling of the carbonate host rock around and below the roots; d: Goethite glaebule (black) with circumgranular spar-filled cracks, P.P.L.; e: Calcified rhizoliths and rhizocretions in iron-rich soil matrix; f: Alveolar-septal structure showing branched ferruginated root hairs or rootlets (black) encrusted by siderite and calcite, C.P.; g: Field photograph showing the uppermost rooty duricrust of the calcimorphic paleosol profile; h: Tubules and cellular structure of goethite (white) and calcite (dark grey), R.L.

laterally into areas displaying alveolar-septal structure (Fig. 8f) which may indicate fungal or bacterial activities around root hairs or root voids (Wright et al., 1988). The soil matrix consists of earthy goethite and hematite mixed with red-stained pelleted calcareous mud within which relics of decomposed carbonate fragments, fossil molds, terrigenous quartz grains, tubular voids and glaeboles and pisoliths of goethite are embedded. The pelleted calcareous portions correspond to the pelleted calcrete texture of Read (1976). A population of vertically arranged ferruginated root molds and rootlets are common along the upper part of this horizon. Cements are often restricted to rhizoliths and rhizocretions and are represented by colloform goethite, siderite, ankerite and orthosparite, arranged according to their order of formation.

Horizon IV, up to 30 cm thick, displays remnants of dissected rooty duricrust, which was once a continuous hard sheet (Fig. 8g). This hard cap is vascular in nature, dark brown to black and is formed almost entirely of interwoven ferruginated rhizoliths and rhizocretions. Polygonal cracks and irregular vertical partings are common. Fracture planes usually have a dull porous earthy appearance. Goethite and spar-filled tubules and cylindrical holes, calcified alveolar and microcodium textures are observed within the ferruginated root molds and casts (Fig. 8h). A late cement of siderite and calcite is apparent at different sites.

- Pedogenesis and calcimorphic soil formation

1. The development of this soil type above the Middle Miocene Um Mahara carbonates provides evidence of syn-rift exposure and drop in the relative sea-level. This is genetically related to post Um Mahara pre Abu Dabbab rift faulting accompanied by related extension of the rift shoulder, eastward migration of the shoreline and sea-level fall.
2. The composition and textural characteristics of this soil type can be correlated with those of the alkaline calcimorphic soils (calcareous terra-rossa or rendzinas) of semiarid climate (Fitzpatrick, 1971; Birkeland, 1984; Zonn, 1986).
3. Pedoturbation processes caused by biological activities of plant roots, fungi, algae and bacteria and other agents such as hydration-dehydration, translocation and aggregation are the main factors controlling the disruption and dissolution of the country rocks and the accumulation of red earth associated with a considerable amount of reprecipitated carbonate minerals. The calcified and ferruginated plant remain indicate former existence of organic activity and thus biochemical processes during the pedogenesis.
4. During the humid periods, the dissolution of the host carbonate rocks is favoured due to the decrease in pH and increase in CO_2 content of the soil water as a result of plant and microorganism respiration and organic matter decomposition. The carbonates dissolve and move as Mg^{+2} , Ca^{+2} and HCO_3 with soil water, while Fe remain insoluble or

forms Fe^{++} ions or organic complexes and accumulates on the top of the profile as sesquioxides. The iron sesquioxides together with calcareous mud and carbonated and colloidal pore water constitute the main components of the produced soil. The availability of Fe in the soil is governed chiefly by the pH and state of oxidation. The earthy goethite and hematite indicate deposition from suspension, while the colloform goethite indicates deposition from pore soil colloids. The continuous concentration of the aggressive organic-rich soil material and water with the associated vegetation and their downward migration and translocation would help in the continuous dissolution and lowering of the underlying bed rocks. The Mg^{+2} , Ca^{+2} and HCO_3 contents might increase to the point of saturation after which further dissolution of the host rocks is not possible. The development of siderite and ankerite in the present soil profile reveals that Mg^{+2} and Fe^{+2} were sufficient in the carbonated pore soil water.

5. During the arid periods and with lowering in the CO_2 content of the soil water, as a result of evapotranspiration of the soil moisture and decrease in the biological activity, reprecipitation of carbonate minerals proceeds. With gradual decrease in the Fe^{+2} content of the pore soil water relative to Mg^{+2} and Ca^{+2} and in alkaline environment, deposition of ankerite and calcite would take place in preference of siderite.

SUMMARY AND CONCLUSIONS

1. Two types of paleosols are detected in Um Gereifat mine area: a pre-rift acid alumino-ferruginous latosol and a syn-rift alkaline calcimorphic paleosol.
2. The first one demarcates pre-rift paleoerosion surface formed during a prolonged period of soilification of Precambrian granite under tropical to subtropical paleoclimate. It is concluded that this latosol type has been generated through three stages induced lateritization and secondary bauxitization during the periods of active weathering followed by a fourth stage of natroalunitization during the general desiccation of the produced laterites. Stage I implies the formation of saprolite by partial desilication and hydration of the parent rocks. Stage 2 encompasses the formation of Al and Fe rich laterite at the top of the profile as a result of ultimate desilication and hydrolysis. Stage 3 comprises secondary bauxitization with differential leaching of Al, Si and Fe and downward migration of the latter. This led to the formation of an Al-rich zone within the laterite at the top and an Fe-rich zone at the bottom, as well as the development of gibbsite in the uppermost Al-rich zone by desilication and hydrolysis of kaolinite. Stage 4 comprises the formation of natroalunite in the uppermost Al-rich zone at the expense of the early formed kaolinite and possibly gibbsite during the general desiccation of the laterites.

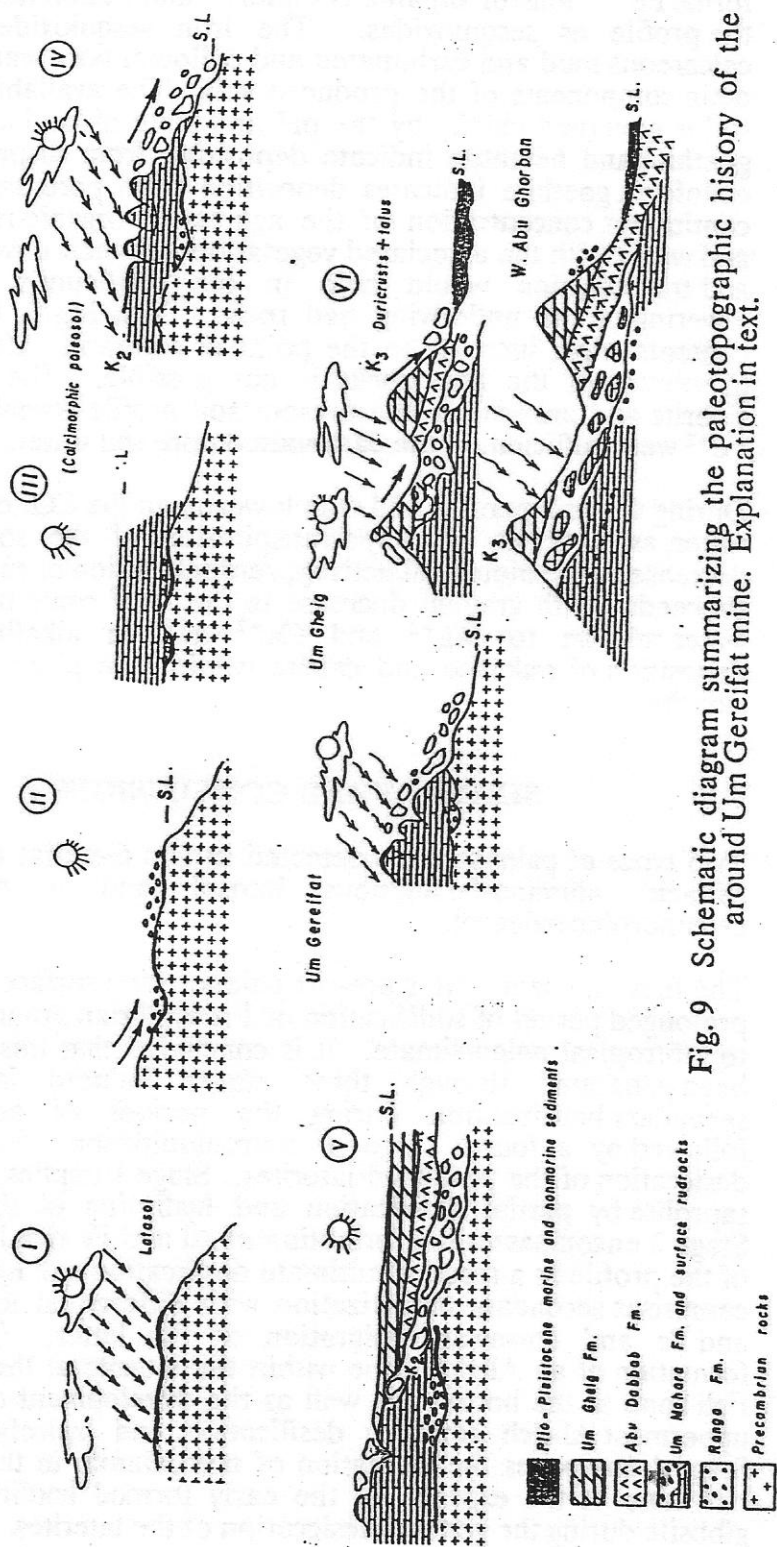


Fig. 9 Schematic diagram summarizing the paleotopographic history of the area around Um Gereifat mine. Explanation in text.

3. The syn-rift alkaline calcimorphic paleosol is genetically related to post Um Mahara-pre Abu Dabbab uplifting phase, sea-level fall and paleokarstification under vegetation cover of semiarid paleoclimate. Pedoturbation processes caused by biological activities, hydration-dehydration, aggregation and translocation were responsible for the accumulation of red earths rich in rhizoliths and associated with considerable amount of reprecipitated carbonates.
4. The pre- and syn-rift paleoerosion surfaces and the related paleosols, duricrusts and surface products are used to understand the paleotopographic history of the Um Gereifat rift sector (Fig. 9). Stage I (Fig. 9) comprises the pre-rift solification and latosol formation under tropical to subtropical paleoclimate (Early Oligocene ?). Stage II encompasses the deposition of the proto-rift continental sediments (Ranga Formation, Late Oligocene-Early Miocene). Stage III comprises the deposition of the Um Mahara Formation uplifting and relative sea-level fall; paleokarstification (K_2) under semiarid paleoclimate with development of calcimorphic paleosol along paleohighs and accumulation of rudrocks in paleolows. Stage V represents the deposition of the Abu Dabbab and Um Gheig formations (Miocene-Pliocene). Stage VI encompasses the post-Um Gheig uplifting and relative sea-level fall; paleokarstification of the paleohighs (K_3) and deposition of the Plio-Pleistocene marine and non-marine sediments along the eastern shoreline. Notes: the intra-Um Mahara paleokarst (K_1) is not represented; Quaternary runoff regimes modified the pre-existing landforms.
5. The intimate genetic relationship between these Paleoerosion surfaces and the formation of laterite and karst-related economic deposits encourage the use of these surfaces as a basis for further exploration.

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العوامل المسببة لتكوين تربة قديمة وما
بها من معادن الجبسيات والنااتروالونيت
فى منطقة ام جريفات على ساحل البحر الاحمر، مصر

مرتضى مراد طه العارف
قسم الجيولوجيا - كلية العلوم - جامعة القاهرة

فى منطقة ام جريفات على ساحل البحر الاحمر بمصر امكن
التعرف على نوعين مختلفين من التربة القديمة ذو وضوع
استراتيجافى وطريقة تكوين مختلفة وهما:

- (١) تربة لاتيرينية حمضية غنية بالالومنيوم والحديد تكونت قبل
تصدع البحر الاحمر.
- (٢) تربة كلسية قلوية تكونت اثناء تصدع البحر الاحمر.

وقد تم فى هذا البحث تحديد التركيب المعدنى
والانسجه الصخرية لكل نوع تربيه على حده وكذلك التعرف على
الظروف المناخية القديمة والعوامل الكيميائية والبيولوجية
التي ادت الى تكوين كل منهما.

اثبتت الدراسة ان النوع الاول من التربيه الاتيريتيه
قد تكون نتيجة تعرض صخور الجرانيت التابعة لعصر ما بعد
الكامبيرى لمناخ مطير استوائى او شبه استوائى وعلى ثلاث
مراحل متتابعه شامله تكوين الاتيريت وعمليات بوكسيتيه
ثانويه تكون على اثرها معدن الجبسيات تلى ذلك مرحله رابعة
اثناء جفاف التربيه الاتيريتيه والبوكسينية المتكونة صاحبها
تكوين معدن النااتروالونيت.

النوع الثانى من التربيه القديمه تكون على صخور
كربوناتية تابعة لعصر المايوسين الاوسط نتيجة تعرضها لعمليات
كارستيه صاحبته مناخ شبه جاف وتحت غطاء نباتى.

التعرف على هذه الانواع من التربيه القديمه ووضعها
الاستراتيجافى ساعد على استنتاج التطور الطبوغرافى لمنطقة
الدراسه قبل واثناء الحركه التكتونيه المصاحبه لتصدع البحر
الاحمر.